Forest Resources of the Apache-Sitgreaves National Forest

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Apache-Sitgreaves National Forest

Arizona

About the author

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The Interior West Forest Inventory and Analysis (IWFIA) program of the USDA Forest Service, Rocky Mountain Research Station, as part of its national Forest Inventory and Analysis (FIA) duties, conducted forest resource inventories of the Southwestern Region (Region 3) National Forests. This report presents highlights of the Apache-Sitgreaves National Forest 1996 inventory, including tree population estimates and summaries of commonly requested variables.

The information presented in this report is based solely on the IWFIA inventory sample (USDA 1996a). The data could be summarized in other ways for different purposes (see "For further information" on the inside back cover for the national FIA database and related contacts). Supplemental documentation and inventory terminology can be found in O'Brien (2002), USDA (2002a), or on the World Wide Web at http://www.fs.fed.us/rm/ogden. Changes in terminology or procedures may limit comparisons with previous estimates and summaries for this area. Additional data collected for the Apache-Sitgreaves National Forest, used separately or in combination with IWFIA data, may produce varying results.

Since the results tabulated in this report reflect data collected by field crews chiefly during the year 1996, changes in forest characteristics that have taken place since that time are not addressed. Any trends or disturbances (such as fire) that have occurred after 1996 will be discussed in future reports on the Apache-Sitgreaves National Forest.

Description of the Forest

The Apache-Sitgreaves National Forest administers 2,015,690 acres (USDA 1996b) of which 88 percent is classified as forest land and 12 percent nonforest or water. This report describes the characteristics of the forest land sampled on the Apache-Sitgreaves National Forest. *Forest land* is land that is at least 10 percent stocked (or formerly stocked) with live tally tree species and is greater than 1 acre in size and 120 feet wide. Based on the predominate tree species present, forest land can be further subdivided into two land categories: timberland and woodland (fig. 1). *Timberland* is forest land where the predominance of tree species tallied have been traditionally used in the wood products industry, such as ponderosa pine and Douglas-fir. *Woodland* primarily includes tree species that typically
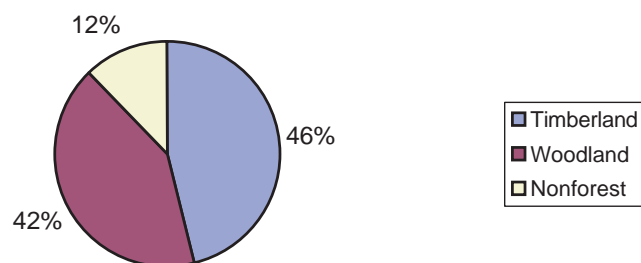
Figure 1—Percent accessible forest land by land type, Apache-Sitgreaves National Forest.

do not conform to breast height diameter measurement or have not been traditionally used for industrial wood products, such as pinyon pine, junipers, and oaks. Focusing on forested land only, 53 percent is timberland and 47 percent is woodland.

Eleven percent of the total forested area administered by the Apache-Sitgreaves National Forest is reserved land, meaning that it has been withdrawn from management for production of wood products, such as wilderness areas. The first section of this report presents summaries of timber and woodland species for all forest land, including reserved designations. A subsequent section addresses nonreserved timberland only and includes estimates for timber species sampled on the Apache-Sitgreaves National Forest.

## Total forest land: highlights of our inventory

Forest type—Forest resources are often described using a forest type classification. *Forest type* refers to the predominant tree species in a stand, based on plurality of tree stocking. *Stocking* is an expression of the extent to which growing space is effectively utilized by live trees.

Figure 2 presents the distribution of forest land area on the Apache-Sitgreaves National Forest by sampled forest type. Ponderosa pine and pinyon-juniper woodlands clearly dominate the forest type coverage. While the ponderosa pine forest type, at 42 percent, covers the largest extent of forest land, the combined total of pinyon-juniper and juniper types all but equals that percentage. The remaining 17 percent comprises a variety of timber and woodland types including evergreen and deciduous oaks,

Douglas-fir, aspen, white fir, Engelmann spruce, mesquite, spruce-fir, blue spruce, and miscellaneous species.

A field plot may sample more than one condition (stand). A forest *condition* is generally defined as an area of relatively homogeneous vegetative cover that meets the criteria for forest land. Forest type is one of several attributes that define and separate conditions identified on the plot (for further explanation of conditions, see "About the mapped-plot design" page 11). Table 1 presents the number of conditions and the condition proportions sampled on the Apache-Sitgreaves National Forest by forest type and condition category.
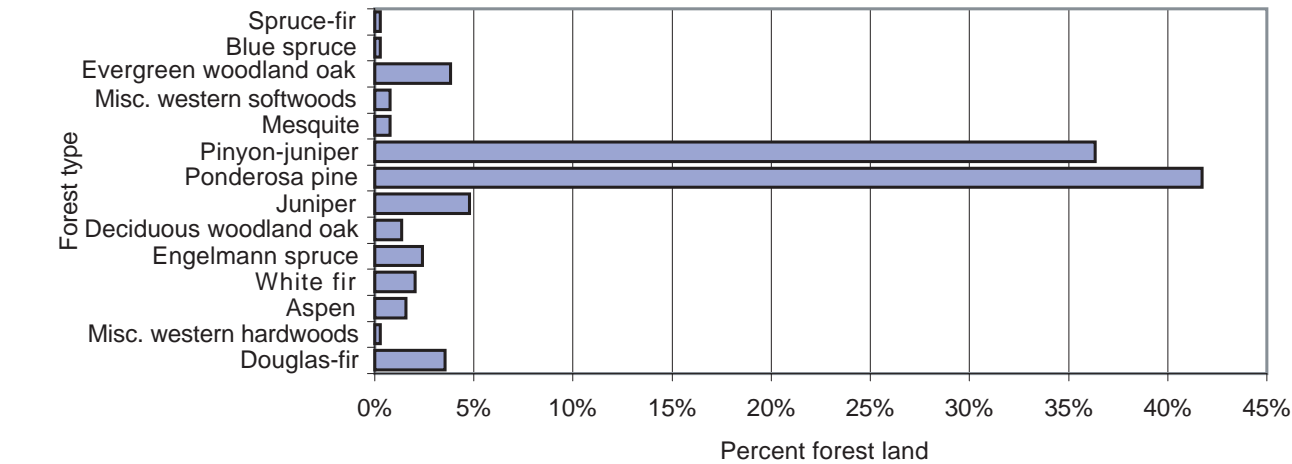
Figure 2—Percent of forest land area by forest type, Apache-Sitgreaves National Forest.

Table 1—Number of conditions and condition proportions on forest land by forest type and land category, Apache-Sitgreaves National Forest, 1996.

| Forest type	Number of conditions[a]	Condition proportions[b]
Timberland		
Ponderosa pine	133	119.1
Douglas-fir	13	10.7
Engelmann spruce	8	7.0
White fir	8	5.8
Aspen	6	5.3
Misc. western softwoods	2	2.0
Blue spruce	2	1.0
Spruce-fir	1	1.0
Total timberland	173	151.9
Woodland		
Pinyon-juniper	111	104.8
Juniper	15	13.0
Evergreen oak	12	10.3
Deciduous woodland oak	4	3.7
Mesquite	3	1.7
Misc. western hardwoods	1	.8
Total woodland	146	134.3
Grand total	319	286.2

[a]Number of conditions by forest type that were sampled. The sum of these numbers is often greater than the total number of plots because a plot may sample more than one forest condition.
[b]Sum of the condition proportions of plots by forest type that were sampled. The sum of these numbers is often less than the total number of plots because of nonforest condition proportions (from plots containing both forest and nonforest conditions) that are not included here.

Number of live trees—Forest land can also be examined by looking at composition of tree species. Figure 3 shows total number of live trees for the most common tree species sampled for three broad diameter classes. Most trees on the forest are in the smallest diameter class, topped by the proliferation of ponderosa pine. Ponderosa pine leads in each of the three diameter classes, while in the 1.0-4.9 inch diameter class alone it accounts for 20 percent of all trees tallied on the forest. A list of common tree species sampled during this inventory is found in table 2. Rare species may not be tallied with the sampling strategy used for this inventory. Species tallied in very small numbers are not shown.

Number and weight of dead trees—Standing and down dead trees are important to forest ecosystems because they provide habitat for wildlife, function as nutrient sinks, and protect the soil from erosion. Approximately 44 million standing dead trees (snags) are 1 inch diameter and greater on Apache-Sitgreaves forest land, averaging 25 snags per acre. Different size snags offer variety in habitat for wildlife. Figure 4 shows the number of standing dead trees by forest type for three diameter size classes. Of the total numbers of snags, 62 percent are between 1 and 4.9 inches diameter, with over half of these occurring in the ponderosa pine forest type. Of the total numbers of snags, 24 percent are between 5 and 10.9 inches diameter. Snags 11 inches diameter or larger make up 14 percent of the total, averaging 3.5 snags per acre. Many of these large snags are found in the ponderosa pine (40 percent) and pinyon-juniper (27 percent), with fewer snags recorded in other forest types.

The amount of down dead material can contribute significantly to forest fuel loads and fire potential. Approximately
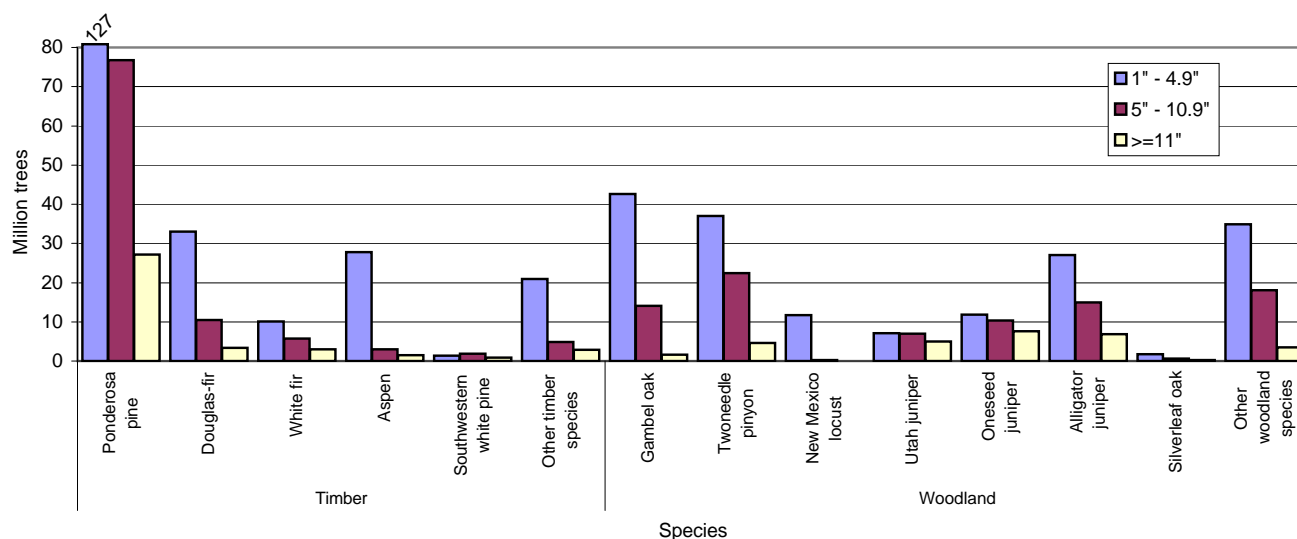
Figure 3—Number of live trees 1 inch diameter and greater on forest land by species and diameter-size class, Apache-Sitgreaves National Forest. The 1-4.9 inch class for ponderosa pine was condensed to improve display (actual value is 127,310,137 trees).

Table 2—Net volume, basal area, and biomass on forest land by species, Apache-Sitgreaves National Forest, 1996.

Species	Volume (million cubic-feet)	Basal area (million square feet)	Biomass (million tons)
Ponderosa pine	1,162.2	60.9	22.7
Douglas-fir	169.0	8.5	3.4
Alligator juniper	139.6	15.9	1.7
Two-needle pinyon	137.1	11.6	1.6
White fir	117.2	6.1	2.1
Engelmann spruce	102.5	3.8	1.5
Oneseed juniper	100.5	15.2	1.3
Utah juniper	71.4	10.3	0.9
Gambel oak	64.8	5.8	1.9
Aspen	57.3	2.7	1.1
Southwestern white pine	44.3	2.0	0.7
Arizona white oak/gray oak	29.2	6.3	1.0
Corkbark fir	19.7	0.8	0.3
Rocky Mountain juniper	7.8	0.6	0.1
Subalpine fir	6.5	0.3	‡
Emory oak	5.8	0.9	0.2
Border pinyon	5.5	0.6	‡
Silverleaf oak	3.3	0.5	‡
Arizona cypress	2.0	0.2	‡
Arizona pinyon pine*	1.4	0.2	‡
Blue spruce	1.4	†	‡
Singleleaf pinyon*	1.0	†	‡
Evergreen – oak	0.8	0.1	‡
New Mexico locust	0.7	†	‡
Western honey mesquite	0.4	0.1	‡
Chihuahua pine	0.3	†	‡
Velvet mesquite	0.2	†	‡
Total** (all tree species)	2,251.9	153.6	40.9

† less than 100,000 sq ft
‡ less than 100,000 tons
* In the FIA inventories of Arizona and New Mexico, single-needle varieties of pinyon pine were not consistently identified. They could be listed as either Singleleaf or Arizona pinyon.
** numbers do not add to total due to rounding
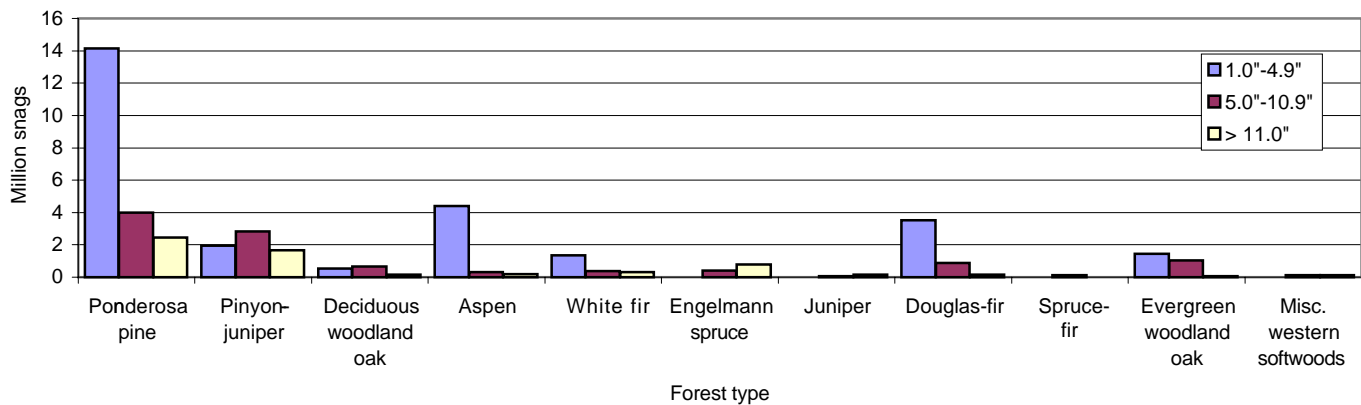
Figure 4—Number of standing dead trees 1 inch diameter and greater on forest land by forest type and diameter size class, Apache-Sitgreaves National Forest.

1.5 million tons of down dead trees are on the Forest, averaging .86 tons per acre. This estimate includes the merchantable bole and bark of trees 5 inches diameter and greater. Forty-five percent of this estimate is from ponderosa pine.

Tree and stand size–The size distribution of trees is an indicator of diversity across a landscape. Figure 5 displays the tree size distribution by diameter class on the Apache-Sitgreaves National Forest. Sixty percent of all live trees are from 1 to 4.9 inches diameter. Twenty-nine percent of all live trees are from 5 to 10.9 inches diameter, and 11 percent are 11 inches diameter and greater.

Stand-size class is a categorization of forest land based on the predominant diameter-size of live trees that contribute to the plurality of stocking in a stand. The large diameter class includes softwoods 9 inches diameter and greater, and hardwoods 11 inches diameter and greater; the medium diameter class includes softwoods 5 to 8.9 inches diameter, and hardwoods 5 to 10.9 inches diameter; and the small diameter class (saplings and seedlings) includes all trees under 5 inches diameter. In terms of stocking, fewer large-diameter trees compared to small-diameter trees are required to fully utilize a site; therefore, large diameter trees have a greater impact on determining stand-size class. Figure 6 displays a breakdown of forest land by stand-size class. Approximately 85 percent of the stands have a plurality of stocking from large trees and 3 percent are nonstocked as a result of recent disturbance, such as burning or cutting.
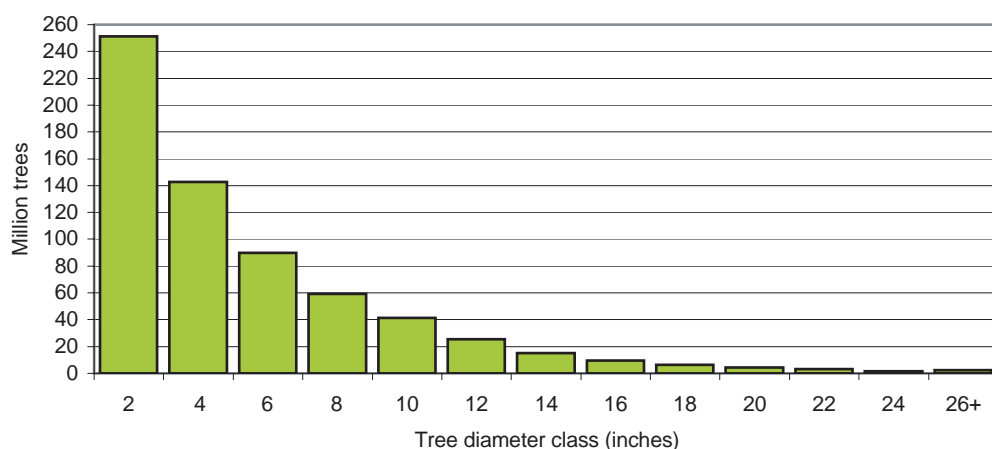
Figure 5—Number of live trees by 2-inch diameter class on forest land, Apache-Sitgreaves National Forest.
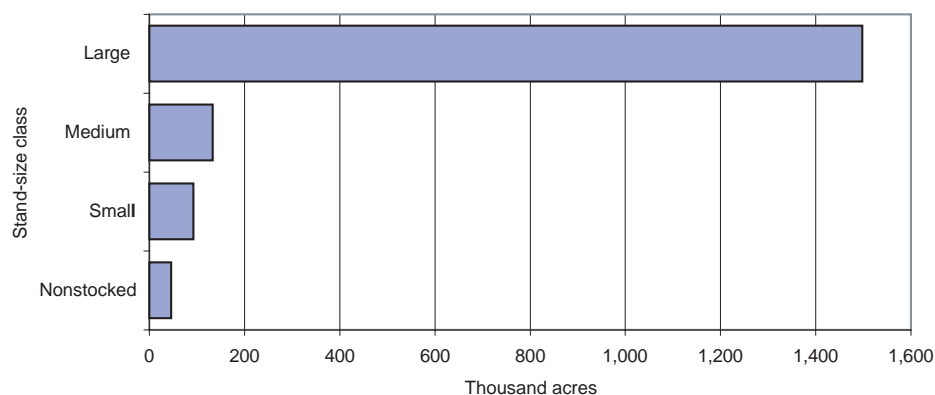

Figure 6—Forest land area by stand-size class, Apache-Sitgreaves National Forest. Large trees include softwoods 9 inches and greater, and hardwoods 11 inches and greater; medium trees are softwoods 5 to 8.9 inches and hardwoods 5 to 10.9 inches; saplings/seedlings are trees less than 5 inches.

Wood volume, basal area of live trees, and biomass—In general, estimates of volume, basal area, and biomass describe the amount of wood fiber in the forest. Each estimate summarizes different parts of a tree and therefore has different applications. For example, volume relates to wood products, basal area to tree or stand density, and biomass to total tree or stand production. In table 2, volume represents the amount of wood fiber in the merchantable bole of a tree. Basal area estimates include the cross-sectional area of a tree stem (bole) at the point where diameter is measured. Biomass represents the amount of wood fiber in terms of oven-dry weight including the tree boles, bark, and branches (not foliage). Table 2 shows a breakdown by all sampled species of net volume, basal area, and biomass for live trees 5 inches diameter and

greater on the Apache-Sitgreaves National Forest. Ponderosa pine leads all species in overall volume (52 percent), basal area (40 percent), and biomass (55 percent).

Figure 7 shows the distribution of net volume of wood in trees by diameter class on Apache-Sitgreaves forest land. While the number of trees declines with larger diameter classes (see fig. 5), volume maximizes at diameter classes from 10 to 12 inches before tapering in the largest size classes.

Another way to look at wood volume is by forest type, for which per acre estimates can be computed along with basal area and biomass (table 3). These numbers include the many different species that can occur together within each forest type. The highest volume per acre on the Apache-Sitgreaves National Forest is in the Engelmann
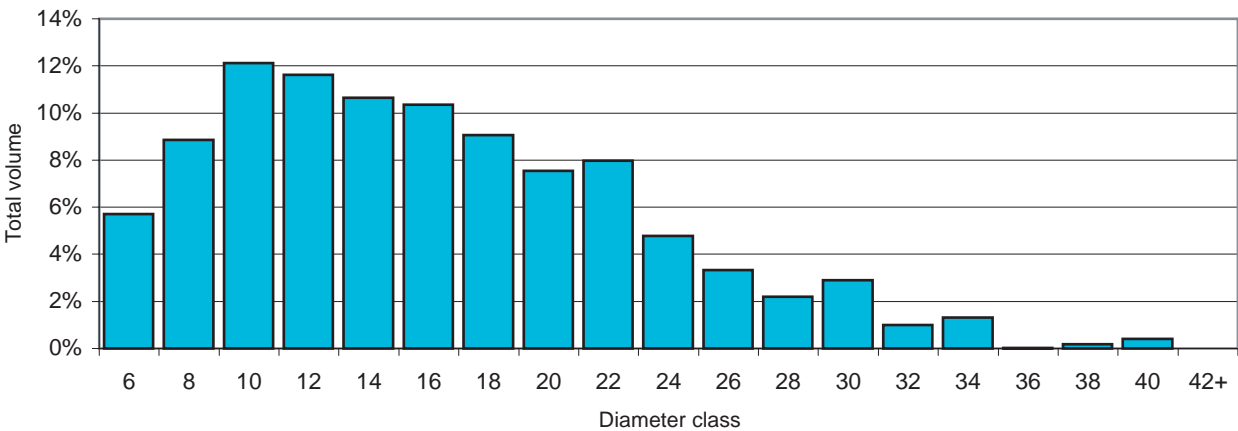
Figure 7—Percent of total net cubic-foot volume of live trees by diameter class, Apache-Sitgreaves National Forest.

Table 3—Net volume, basal area, and biomass per acre on forest land by forest type, Apache-Sitgreaves National Forest, 1996.

| Forest type	Volume (cubic-feet per acre)	Basal area (square feet per acre)	Biomass (tons per acre)
Engelmann spruce	3,235	119	51.4
White fir	3,103	155	55.8
Spruce-fir	2,778	127	51.4
Douglas-fir	2,494	121	47.6
Misc. western softwoods	2,302	108	39.8
Ponderosa pine	1,682	93	33.2
Aspen	1,428	78	27.5
Deciduous woodland oak	817	72	20.7
Pinyon-juniper	669	81	9.2
Juniper	442	54	6.5
Evergreen woodland oak	411	63	9.3
Blue spruce	375	23	6.5
Misc. western hardwoods	214	19	5.7
Mesquite	27	10	1.2
All forest types (combined)	1,273	87	23.1

spruce forest type, followed by white fir and spruce-fir. These three forest types also contain the highest basal area and biomass per acre, as these attributes are strongly correlated with volume.

Many of the forest types listed in table 3 may not be representative due to small sample sizes (see table 1). Only the ponderosa pine and pinyon-juniper forest types have large samples.

Stand density index—Many factors influence the rate at which trees grow and thrive, or die. As tree size and density increase, competition for available resources increases. *Stand density index* (SDI), as developed by Reineke (1933), is a relative measure quantifying the relationship between trees per acre, stand basal area, average stand diameter, and stocking of a forested stand. The concept was developed for even-aged stands, but can also be applied to uneven-aged stands (Long and Daniel 1990; see next paragraph for explanation of even-aged and uneven-aged stands). SDI is usually presented as a percentage of the maximum SDI for each forest type (USDA 1991). SDI was computed for each location using those maximums, and the results were grouped into six classes (fig. 8). A site is considered to be fully occupied at 35 percent of SDI maximum, which marks the onset of competition-related stresses and slowed growth rates (Long and Daniel 1990). Based on FIA sample data, 51 percent of all forest stands in the Apache-Sitgreaves National Forest are considered to be fully occupied.

Southwest stand structure—Stands may be categorized on the basis of tree size, often in terms of their predominate diameter or height class. This works well for stands
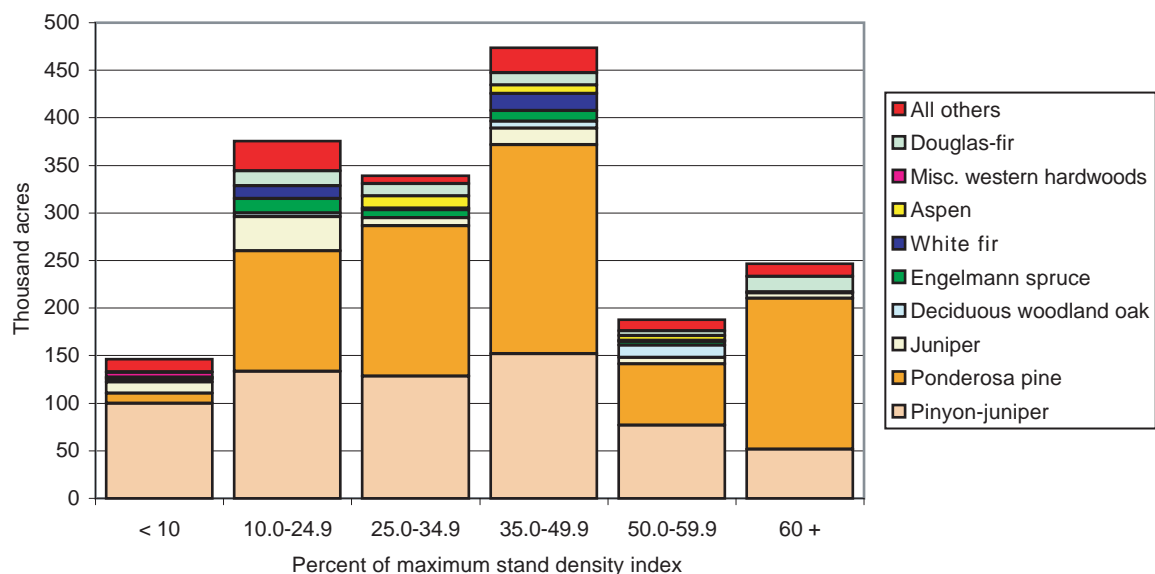
Figure 8—Area of forest land by forest type and percent stand density index, Apache-Sitgreaves National Forest.

where just one or two size classes dominate. Such stands are called single-storied, or even-aged, because they have a structure characterized by a single canopy layer or two closely related layers. Stands having a structure composed of three or more size classes are called multistoried or un-even-aged stands. Contrasting stand structures provide diversity across landscapes. Differences between many layers within a multistoried stand provide vertical diversity.
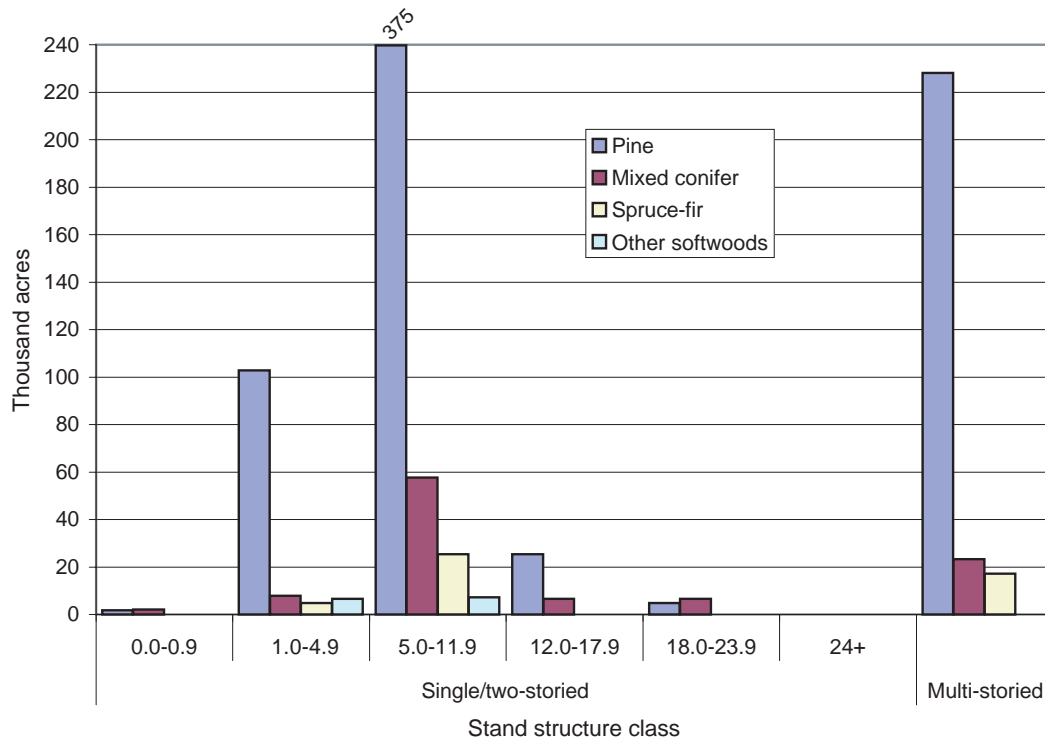
Figure 9 shows area of forest land by stand structure class and diameter class for pine, mixed conifer, spruce-fir, and other softwoods. On the Apache-Sitgreaves National Forest the pine category is made up of ponderosa pine; the mixed conifer category includes Douglas-fir, white fir, and blue spruce; the spruce-fir category contains Engelmann spruce; and the other softwoods group accounts for the remaining commercial species. The values shown are based on analysis of SDI and tree diameter classes, a method developed by the Southwest Region (USDA 2002b). In general, the Apache-Sitgreaves National Forest is represented by both single-storied and multistoried stands, but the distribution within single-storied stands occurs mainly in the 5 to 11.9 inch diameter class.

Growth and mortality—Another measure of forest vigor is net annual growth. Net annual growth is the difference between gross annual growth and losses due to mortality. Field crews assess which trees have died in the past 5 years;

these trees are used to estimate an average annual mortality. Based on this estimate, in 1996 approximately 6.8 million cubic feet of wood 5 inches diameter and greater died on the Apache-Sitgreaves National Forest. Both ponderosa pine and Engelmann spruce generated the highest volume of mortality at just over two million cubic feet. However, Engelmann spruce, along with alligator juniper, had much higher *percentages* of mortality at 82 and 87 percent, respectively. Ponderosa pine exhibited a low mortality percentage, seven percent, because of its very high gross growth volume.

Gross annual growth of all live trees 5 inches diameter and greater on all Apache-Sitgreaves forest land is estimated at 52 million cubic feet. By deducting the estimated mortality from the gross growth we calculated a net annual growth of 45 million cubic feet. Total mortality is about 13 percent of gross annual growth. In figure 10 gross annual growth is compared to mortality for the eight species that include mortality trees. Growth in most species, except Engelmann spruce, far outstrips mortality on the Apache-Sitgreaves National Forest.

Field crews also estimate the causes of mortality, when possible. Forty-five percent of the mortality on the Apache-Sitgreaves National Forest was caused by disease, 28 percent by fire, and 15 percent by insects. The remaining 12 percent was attributed to weather, suppression, and animal damage, in respective order of prominence.


Figure 9—Area of forest land by stand structure class, diameter class, and timberland softwood forest type groups, Apache-Sitgreaves National Forest. Actual value for pine in the 5.0-11.9 class is 375,284 acres.

Understory vegetation—Understory vegetation provides forage and cover for wildlife, contributes to forest fuel load, adds to total forest biomass, and can be an indication of the successional stage of the forest community. On each plot field crews visually estimated crown canopy coverage for four plant groups: tree seedlings and saplings, shrubs, forbs, and graminoids (see USDA 1996a for details). Figure 11 shows the average percent cover of these plant groups on forest land by forest type.

## Nonreserved timberland: highlights of our inventory

Tree and stand size—Forty-eight percent of forest land in the Apache-Sitgreaves National Forest is nonreserved timberland. The distribution of nonreserved timberland by stand size class is presented in figure 12. Eighty-nine percent of the area of nonreserved timberland is found in the 9 inch and larger stand-size class. Similar to all forest land (fig. 6), most of the nonreserved timberland area has a plurality of stocking from large trees.
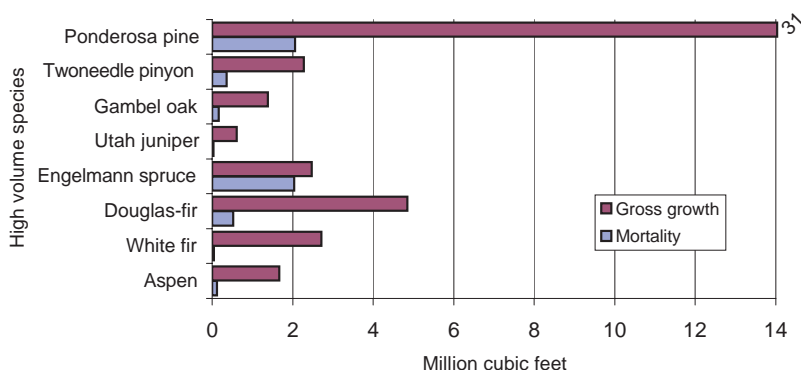
Figure 10—Gross annual growth of live trees 5 inches diameter and greater compared to mortality on all forest land, Apache-Sitgreaves National Forest, 1996. Actual volume for gross growth of ponderosa pine is 31,517,581 cubic feet.
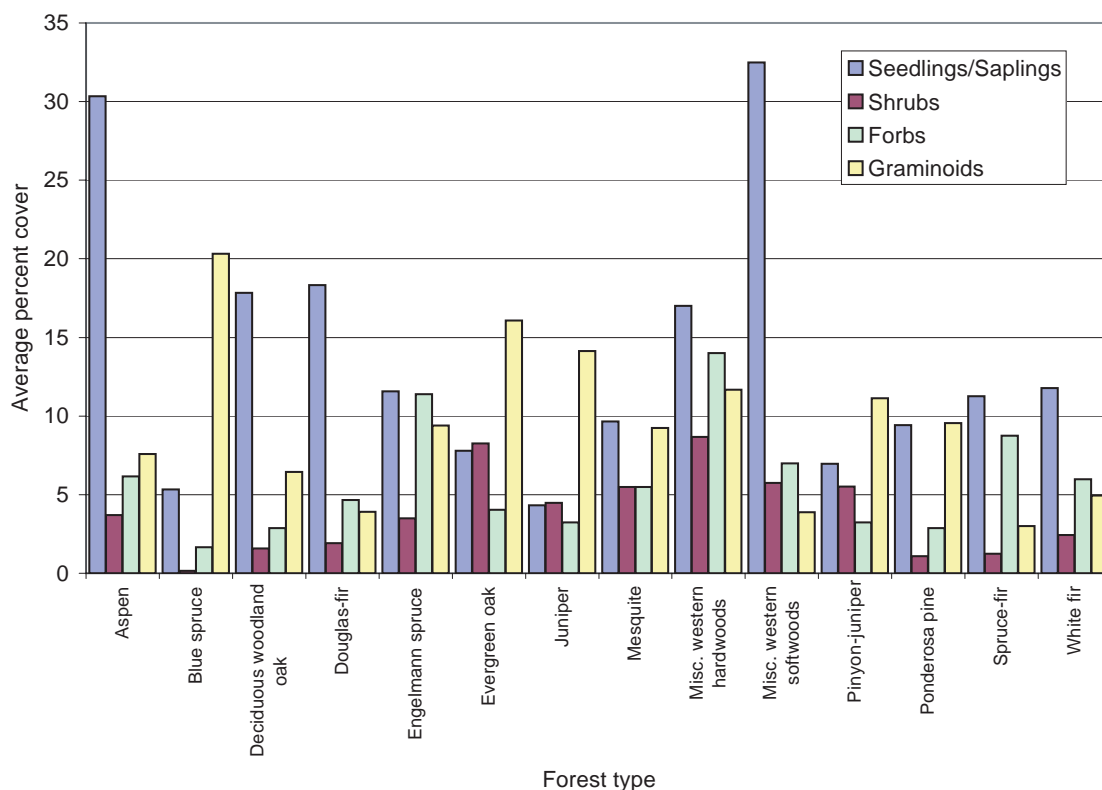
Figure 11—Average percent cover of shrubs, forbs, graminoids, and seedlings and saplings on forest land by forest type, Apache-Sitgreaves National Forest.
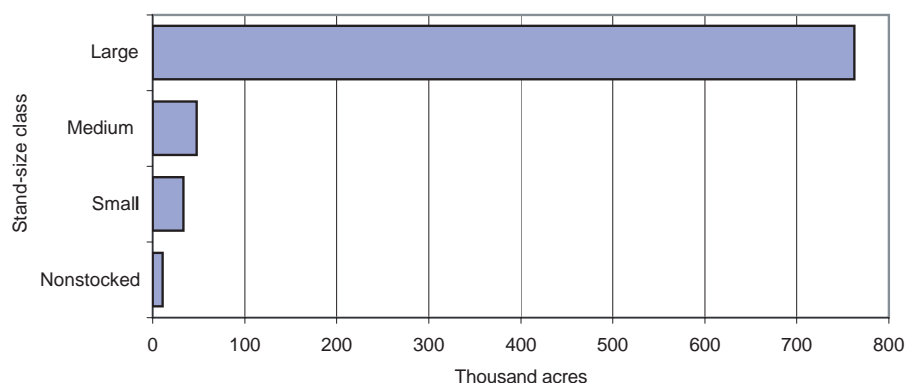
Figure 12—Area of nonreserved timberland by stand-size class, Apache-Sitgreaves National Forest.

Figure 13 shows the distribution of diameter-size classes for growing-stock trees on nonreserved timberland on the Apache-Sitgreaves National Forest. *Growing-stock* trees are live timber species meeting specific standards of quality and vigor. Of all growing-stock trees on nonreserved timberland 19 percent are 9 inches diameter or greater.

Wood volume, basal area, and biomass of growing-stock trees—Table 4 displays net cubic-foot volume, square foot basal area, and tons of wood biomass for growing-stock trees 5 inches diameter and greater by species on nonreserved timberland for the Apache-Sitgreaves National Forest. The total net cubic-foot volume of growing stock on nonreserved timberland is about 1.5 billion cubic feet. Ponderosa pine accounts for 70 percent of this volume. Total basal area for growing-stock trees on nonreserved timberland is estimated at 74 million square feet, with ponderosa pine comprising 72 percent of this total. The total wood biomass is estimated at 28 million tons, with ponderosa pine making up over 72 percent of this amount.

The total net sawtimber volume on nonreserved timberland is estimated at 5.6 billion board feet (Scribner rule).

Sawtimber includes all growing-stock trees 9 inches and greater for softwoods, and 11 inches diameter and greater for hardwoods. Ponderosa pine accounts for the majority, 71 percent, of this volume.

Growth and mortality—Gross annual growth of growing stock on nonreserved timberland on the Apache-Sitgreaves National Forest is estimated to be 40.3 million cubic feet, while mortality is estimated at 3.7 million cubic feet. This calculates to a net annual growth of 36.6 million cubic feet. All of the mortality volume was attributed to seven species, with Engelmann spruce accounting for 55 percent of this total. Gross annual growth is compared to mortality for the top five species in figure 14. Mortality for nonreserved timberland on the Apache-Sitgreaves National Forest is about nine percent of gross annual growth, with the largest mortality-to-growth ratio occurring in Engelmann spruce, where mortality volume is nearly equal to gross growth, yielding only a slight net growth for this species. These results are similar to those shown in figure 10 for trees on all forest land.
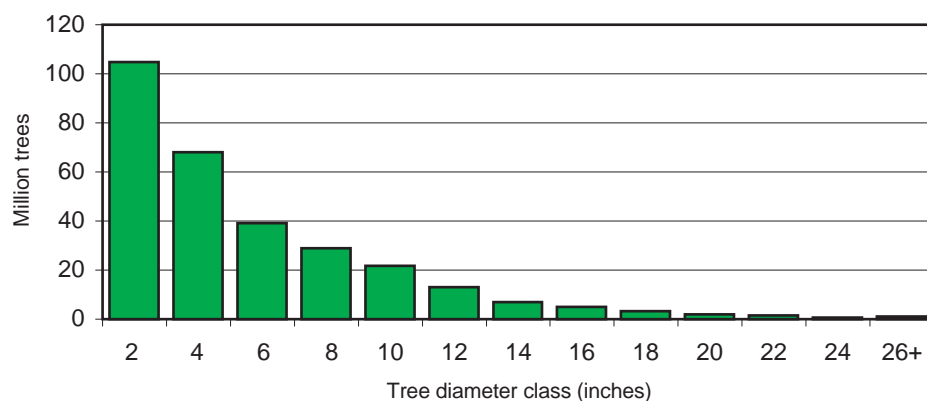
Figure 13—Number of growing-stock trees by 2-inch diameter class on nonreserved timberland, Apache-Sitgreaves National Forest.

Table 4—Net volume, basal area, and biomass of growing-stock trees 5 inches diameter and greater by species on nonreserved timberland, Apache-Sitgreaves National Forest, 1996.

Species	Volume (Million cubic feet)	Basal area (Million square feet)	Biomass (Million tons)
Ponderosa pine	1,030.0	53.6	20.1
Douglas-fir	146.9	7.4	2.9
White fir	97.8	5.2	1.8
Engelmann spruce	73.4	2.9	1.1
Aspen	53.5	2.3	1.0
Southwestern white pine	39.7	1.7	0.7
Corkbark fir	19.7	0.8	0.3
Subalpine fir	6.5	0.3	‡
Arizona cypress	2.0	0.2	‡
Blue spruce	1.4	†	‡
Chihuahua pine	0.3	†	‡
Total*	1,471.2	74.5	27.9

† less than 100,000 square feet
‡ less than 100,000 tons
* numbers may not add to total due to rounding

The inventory methods

About the two-phase design—FIA inventories provide a statistical-based sample of forest resources across all ownerships that can be used for planning and analyses at local, state, regional, and national levels (for further information about the national FIA program, refer to the World Wide Web at http://www.fia.fs.fed.us). IWFIA uses a two-phase sampling procedure for all inventories. Phase one of the inventory is based on a grid of sample points systematically located every 1,000 meters across all lands in the state. Phase one points are assigned ownership and vegetative cover attributes using maps and remotely sensed imagery.

Field crews conduct phase two of the inventory on a subsample of the phase one points that occur on forest land. The sampling intensity is one field plot every 5,000 meters, or about every 3 miles. Phase two plots are stratified based on phase one ownership and vegetation information, and weights are assigned to each stratum based on the proportion of phase one points in that stratum.

About the mapped-plot design—The mapped-plot design was adopted by FIA nationwide by 1995. The predetermined subplot layout uses boundary delineation to classify differing conditions. Most plots sample a single forest condition, therefore delineating conditions is often not required.
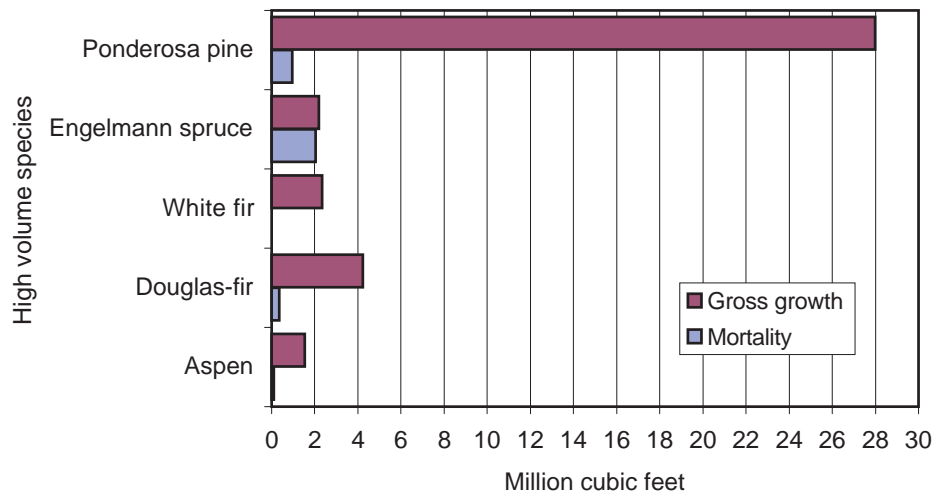
Figure 14—Gross annual growth of growing-stock trees compared to mortality on nonreserved timberland, Apache-Sitgreaves National Forest.

Conditions were separated or mapped based on differences in any of five attributes: forest/nonforest, forest type, stand-size class, stand origin, and stand density. The condition proportion is the fraction of plot area sampled on each condition. The sum of all condition proportions for a plot equals 1.00. Therefore, the number and relative size of plot conditions determines the weighted area (condition proportion multiplied by expansion factor) used for sample expansion.

In summary, there were 326 field plots on the Apache-Sitgreaves National Forest, of which two were determined to be inaccessible. Of the 324 plots that were field

sampled, 279 sampled only forest conditions, 10 sampled both forest and nonforest conditions, and 35 sampled only nonforest conditions.

Standard errors—The sample was designed to meet national standards for precision in state and regional estimates of forest attributes. Standard errors, which denote the precision of an estimate, are usually higher for smaller subsets of data. Percent standard errors for estimates of area, net volume, net annual growth, and annual mortality are presented in table 5. Standard errors for other estimates are available upon request (see "For further information" section on the inside back cover).

Table 5—Percent standard error for area estimate of total forest land, and percent errors for estimates of net volume, net annual growth, and annual mortality for all live trees on total forest land, and growing-stock trees (5 inches diameter and greater) on nonreserved timberland, Apache-Sitgreaves National Forest.

Land class	Attribute	Estimate	Percent standard error
Total forest land (acres)	Area	1,769,303	±2.0
Total forest land (all trees cubic feet)	Volume	2,251,863,899	±5.1
	Growth	45,593,153	±6.8
	Mortality	6,810,220	±30.7
Nonreserved timberland (growing-stock cubic feet)	Volume	1,471,154,158	±7.3
	Growth	36,572,947	±7.8
	Mortality	3,698,228	±44.2

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Selected data for this Forest are part of a national database that houses information for much of the forest land in the United States. This database can be accessed on the Internet at the following web site:

http://ncrs2.fs.fed.us/4801/fiadb/index.htm

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.